

Technical University of Denmark



## Spectro-temporal modulation sensitivity and discrimination in normal hearing and hearing -impaired listeners

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## Introduction

When a signal varies in its properties along the time and frequency, this is considered a modulation. Speech signals exhibit temporal and spectral modulations. The sensitivity to these modulations has been studied in normal-hearing (NH) listeners, yielding temporal, spectral and spectro-temporal modulation transfer functions (Dau et al. 1997, Eddins & Bero 2007, Chi et al. 1999). Recently, Mehraei et al. (2014) showed significant differences between normal-hearing and hearing-impaired (HI) listeners in spectro-temporal modulation (STM) *detection* and also the relation between STM sensitivity to speech intelligibility in noise. Moreover, Henry et al. (2005) showed large differences in STM *discriminations tasks*. The present study attempted to establish the limits of STM perception in NH listeners and two groups of HI (with either good or poor speech intelligibility).

## Motivation

The reduced STM sensitivity in HI listeners has been ascribed to temporal fine structure processing deficits and a loss of frequency selectivity (Bernstein et al. 2013, Mehraei et al. 2014). The main assumption of this study is that the individual differences in STM sensitivity can be related to the **existence of supra-threshold distortions** (Plomp, 1986).

## Research Questions

**Q1: Where are the limits of STM perception in NH listeners for narrow-band noise carriers?**

**Q2: Can supra-threshold distortions be characterized by STM detection thresholds?**

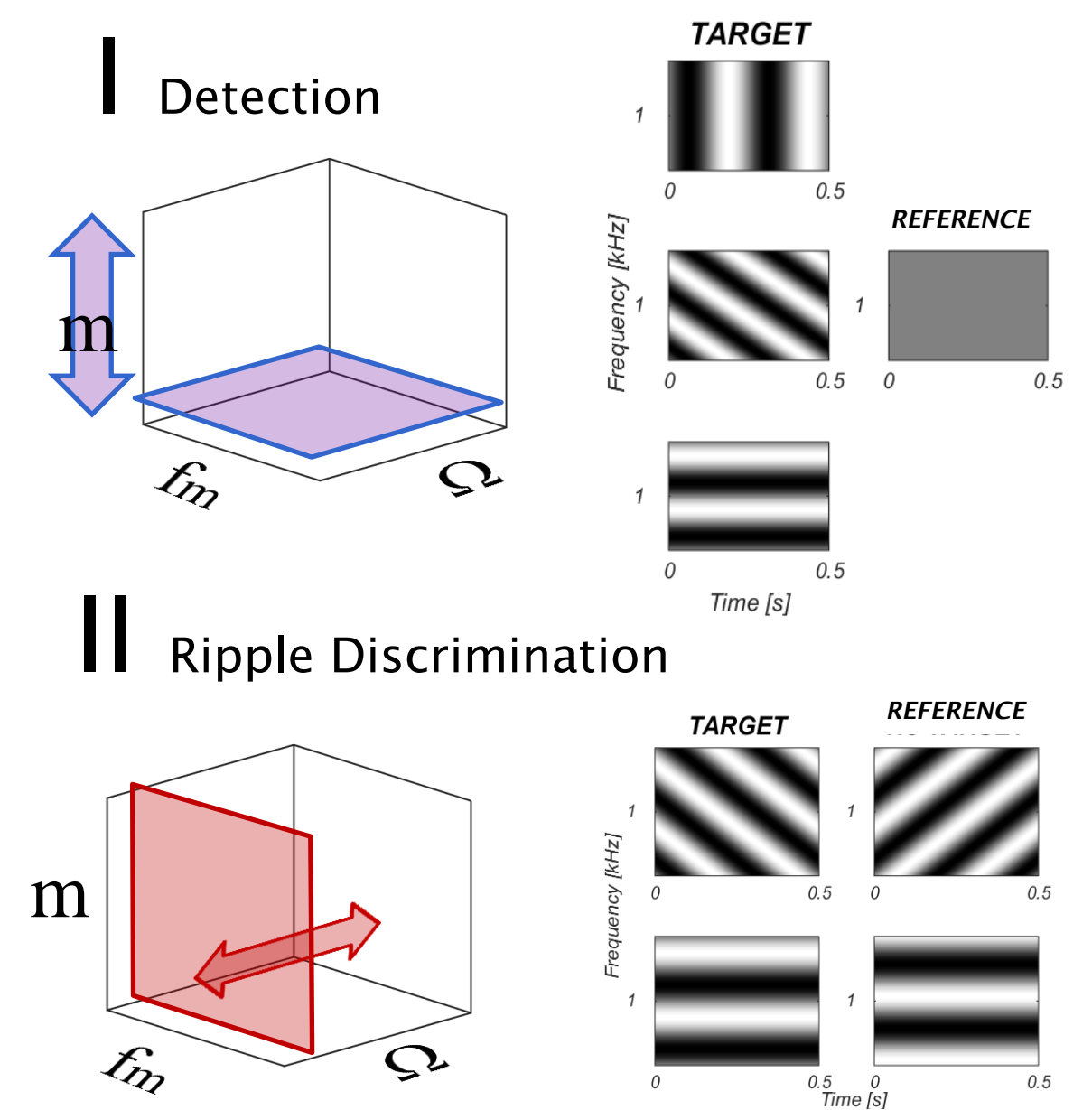


Fig. 1: STM are defined by modulation depth (amount of modulation), modulation frequency ( $f_m$ , cycles per second) and spectral density ( $\Omega$ , cycles per octave). The tasks performed here are **I Detection**: minimum amount of modulation, **II Discrimination**: maximum spectral density for fully modulated ripples.

## Experiment I: Limitations in STM sensitivity and discrimination in NH listeners

### Method

**Subjects:**  
15 Young NH listeners

**Procedure:**  
3AFC, 1-up 2-down

**Stimuli:**  
Level: 35 dB SL  
Modulated 1 octave noise:

- $F_c = 1\text{kHz}$   
 $f_m = 4\text{ Hz}$ ,  $\Omega = 2\text{ c/o}$
- $F_c = 4\text{kHz}$   
 $f_m = 4\text{ Hz}$ ,  $\Omega = 4\text{ c/o}$

### Results

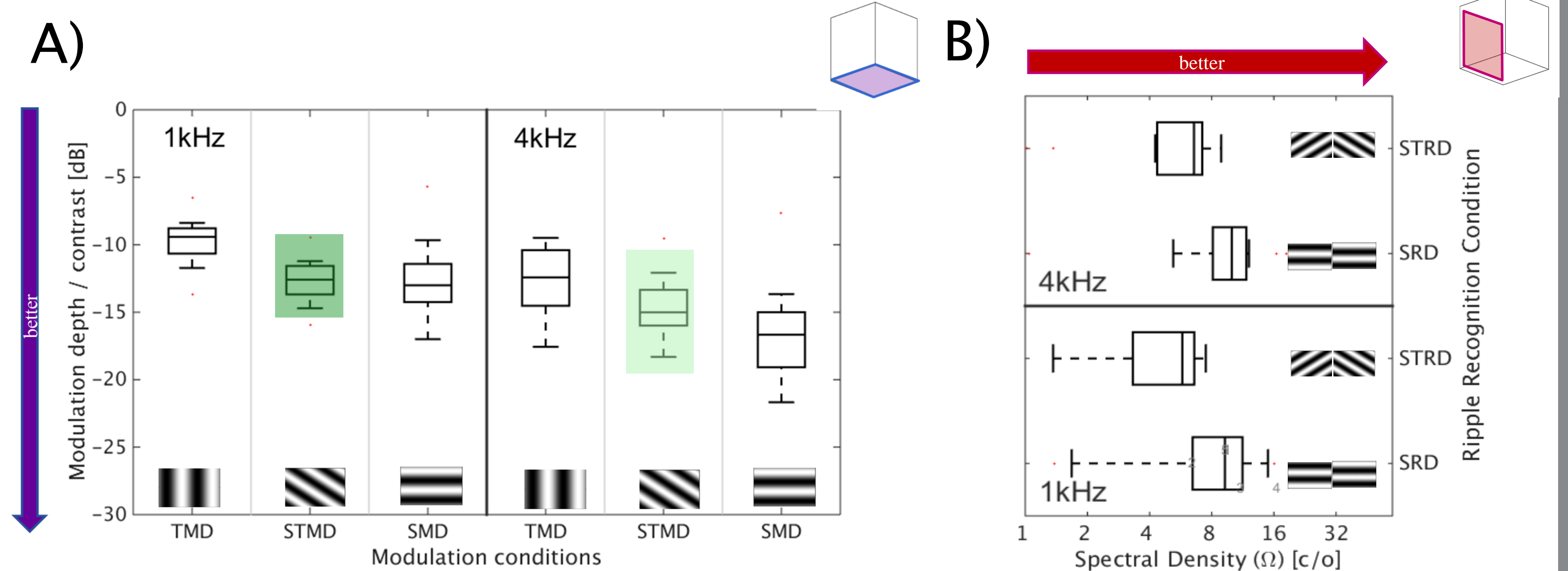
Fig. 2: A) Detection thresholds for temporal (TMD), spectral (SMD) and spectro-temporal modulations (STMD).

⇒ The STMD thresholds were lower (better) than only TMD

B) Spectro-temporal ripple discrimination (STRD) and Spectral (SRD) ripple discrimination for 1-octave band modulated noises.

⇒ There was not significant difference for the two frequency conditions.

⇒ STRD threshold was lower and was found less suitable for a clinical set-up.



## Experiment II: Spectro-temporal modulation sensitivity and hearing deficits

### Method

**Subjects:**  
23 subjects were divided in three groups by means of the SSQ\* questionnaire for Speech:  
5 NH, 9 HI<sub>A</sub>, 9 HI<sub>B</sub>

#### STM detection:

- 2 conditions:
  - 1 KHz,  $f_m = 4\text{ Hz}$   
 $\Omega = 2\text{ c/o}$
  - 4 KHz,  $f_m = 4\text{ Hz}$   
 $\Omega = 4\text{ c/o}$
- Level:  $SRT_q^{**} + 30\text{ dB} + SRT_N^{***}$
- 3 IFC, 1-up 3-down procedure

#### TM detection:

- Same frequencies (1 and 4 kHz) and  $f_m$  (4Hz)

### Hearing Profiles

#### Profile A:

- Speech Spatial Quality hearing scale (SSQ) higher than the average (4.4) (Gatehouse & Noble, 2004)
- Hearing loss and communication handicap is captured by the audiogram

#### Profile B:

- SSQ lower than average
- A speech communication handicap is expected
- Worse frequency and temporal resolution may lead to supra-threshold distortions

### Results

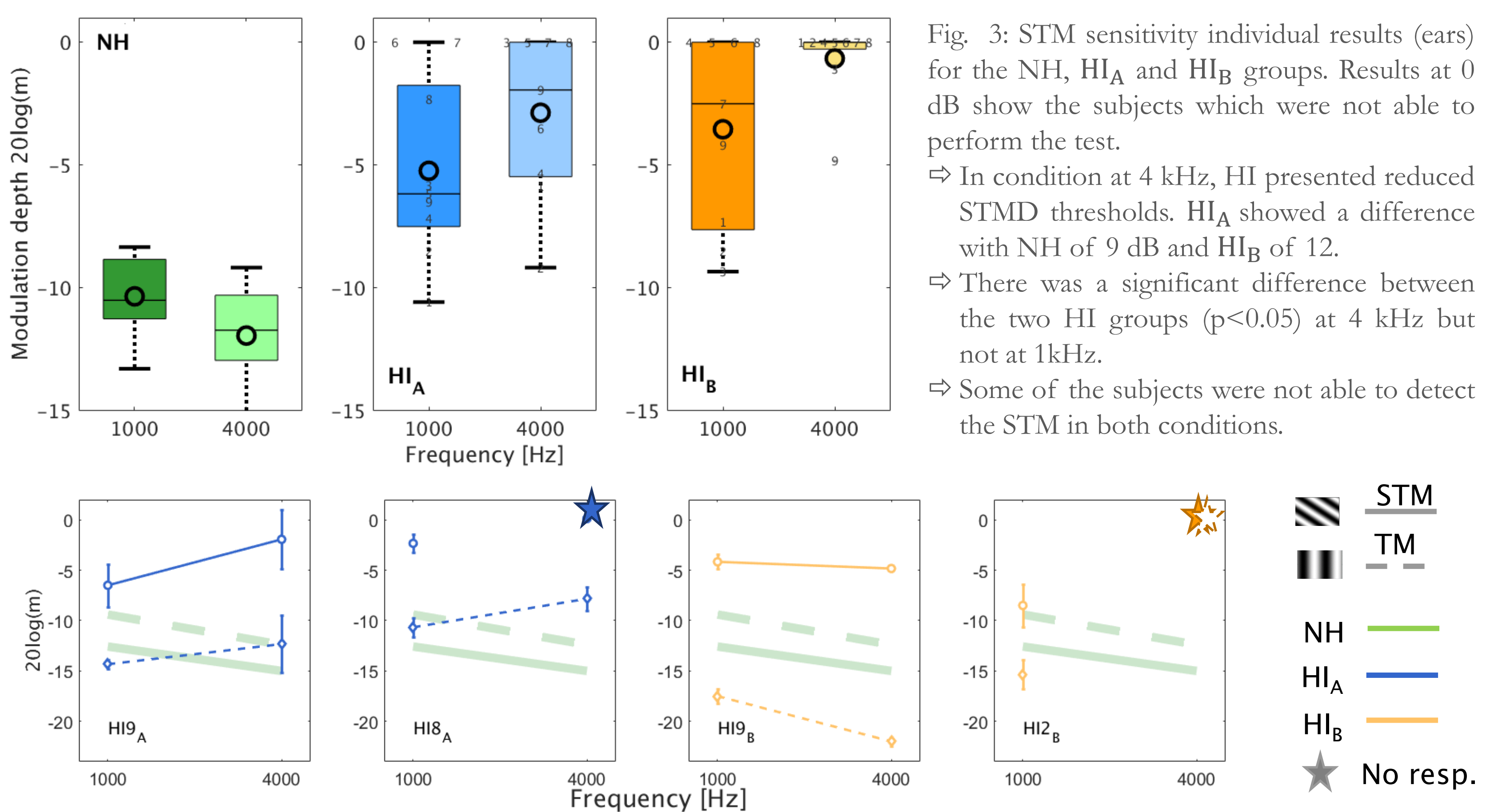


Fig. 3: STM sensitivity individual results (ears) for the NH, HI<sub>A</sub> and HI<sub>B</sub> groups. Results at 0 dB show the subjects which were not able to perform the test.

⇒ In condition at 4 kHz, HI presented reduced STMD thresholds. HI<sub>A</sub> showed a difference with NH of 9 dB and HI<sub>B</sub> of 12.

⇒ There was a significant difference between the two HI groups ( $p < 0.05$ ) at 4 kHz but not at 1kHz.

⇒ Some of the subjects were not able to detect the STM in both conditions.

\* SSQ: Speech, Spatial and Quality  
\*\*  $SRT_q$ : Speech reception threshold in quiet  
\*\*\*  $SRT_N$ : Speech reception threshold in noise

## Conclusion and Outlook

In the present study the HI listeners were divided in two groups by means of the SSQ questionnaire. Significant differences were observed between the two groups in STMD. Overall, these results suggested that the two groups may be affected by different impairments. Within the Better hEARing Rehabilitation (BEAR) project, a new battery test will provide information about the hearing deficits beyond the audiogram. The results from the present study suggests that spectro-temporal modulation detection might be a good candidate for characterizing hearing deficits towards a clinical profiling.

- NH listeners were more sensitive to STM than to purely temporal modulations.
- Some HI listeners were not able to perform the STMD task, especially profile B (with poorer self-reported speech understanding).
- STMD or the threshold difference between STMD and TMD could be part of a clinical test for hearing profiling.

## References

Chi, T., Gao, Y., Guyton, M. C., Ru, P., & Shamma, S. (1999). STMTF and speech intelligibility. *JASA*, 106(5), 2719-2732.  
Dau, T., Kollmeier, B., & Kohlrausch, A. (1997). Modeling auditory processing of amplitude modulation. I. Detection and masking with narrow-band carriers. *JASA*, 102(5), 2892-2905.  
Eddins, D. A., & Bero, E. M. (2007). SMD as a function of modulation frequency, carrier bandwidth, and carrier frequency region. *The Journal of the Acoustical Society of America*, 121(1), 363-372.

Henry, B. A., Turner, C. W., & Behrens, A. (2005). Spectral peak resolution and speech recognition in quiet: normal hearing, hearing impaired, and cochlear implant listeners. *JASA*, 118(2), 1111-1121.  
Bernstein, J. G., et al (2013). Spectrotemporal modulation sensitivity as a predictor of speech intelligibility for hearing-impaired listeners. *JASA*, 24(4), 293.  
Mehraei, G. et al (2014). Spectrotemporal modulation sensitivity for hearing-impaired listeners: Dependence on carrier center frequency and the relationship to speech intelligibility. *JASA*, 136(1), 301-316  
Plomp, R. (1986). A signal-to-noise ratio model for the speech-reception threshold of the hearing impaired. *Journal of Speech, Language, and Hearing Research*, 29(2), 146-154.